Module 3: Technology, Learning, and the Brain (Complete Summary)

1. Change of the World: from 3D to 2D

Based on the work of Susan Greenfield, the fundamental premise for this module is that we are living through an unprecedented environmental shift from a "3D world" to a "2D world."

The 3D to 2D Transition

The two environments can be defined as:

- **3D World:** The physical, tangible world of "real life" in which human brains evolved.
- **2D World:** The screen-mediated environment (PCs, smartphones, tablets) where we spend an ever-increasing portion of our time.

This new 2D environment has specific, defining characteristics that differ from the 3D world:

- Technology is pervasive ("Tech is everywhere").
- Information is de-contextualised ("Facts can be accessed at random").
- There are no lasting consequences ("Actions can be reverse[d]").
- Time is compressed and non-linear ("Time is short").
- There is an expectation of 24/7 responsiveness and productivity.

Why This Change Is Unique

This technological shift is different from previous ones (like the invention of the car or electricity) for two main reasons:

A) Pervasiveness
Digital technology is not just a tool; it has become an all-encompassing environment.

- **Statistics (citing 2011-2012 data; e.g., Prensky, 2001; Keen, 2007; Selwyn, 2009; KidScape, 2011):**
  - **Commerce:** 71% of US adults bought goods online.
  - **Socialising:** 22.5% of all online time was spent on social networks.
  - **Relationships:** Over 1/3 of US couples married 2005-2012 met online.
- **Behaviour:** It has become the default way to experience life. A 2012 Badoo survey found 24% of social media users reported "missing a key moment" in real life because they were too busy posting about it (Badoo, 2012).
- **Functionality:** A single device (smartphone/PC) has absorbed dozens of separate real-world functions (work, maps, alarm clock, shopping, news, communication, leisure, etc.).

B) From "Means" to "End"

This is a crucial distinction. A car is a means to an end (getting from A to B). Electricity is a means to an end (powering a light).
In contrast, the digital environment (like a social network) has become an *end in itself*. It is the "place" where people live, socialise, and build their identity, not just a tool to accomplish a separate task.

The Generational Divide

This 2D transition is the first to create a profound generational gap, as defined by Marc Prensky (2001):

- **Digital Immigrants:** Those born in the 3D world who "learned the language" of technology as adults. Like someone learning a second language, they will always retain an "accent" —a "foot in the past."
- **Digital Natives:** Those born *into* the 2D world. It is their "mother tongue." They have known nothing else.

The most common modern scenario is that **parents are Digital Immigrants, while their children are Digital Natives**. This creates a fundamental gap in how these two generations perceive and interact with their environment.

2. How Our Brain Works and Changes

This section establishes the biological basis for the lecture's core argument: the human brain is not fixed but is profoundly shaped by experience. This principle is known as **neuroplasticity**.

The Core Principle: The Brain Adapts

The brain is sculpted by a lifetime of experiences. As brain development expert Bryan Kolb (2009) states, "Anything that changes your brain, changes who you will be."

This is not a passive process. Experience alters brain activity, which in turn changes gene expression. Behavioural changes reflect physical alterations in the brain, and conversely, behaviour can change the brain.

Evidence for Neuroplasticity

A large body of research demonstrates that the brain physically adapts to the environment and to specific training.

- **Animal Studies:**
  - **Historical Evidence (Malacarne, 1783):** Trained dogs and birds showed an increased number of folds in the cerebellum (Doidge, 2007).
  - **Enriched Environments (Rosenzweig, 1964):** Rats in "enriched cages" (with toys)

developed superior problem-solving skills and measurable physical brain changes compared to rats in "standard cages."
    - **Gene-Environment Interaction (Van Dellen et al., 2000):** Mice with the Huntington's disease gene raised in an enriched environment developed movement problems much later and less severely, showing how "nurture" (environment) interacts with "nature" (genes).
- **Human Studies (Specific Skills):**
    - **Early Life Plasticity (Bavelier & Neville, 2002):** In cases of early blindness, the visual cortex is not being used for its normal job, so it adapts to process sound inputs. This "cortical remapping" can result in sharper hearing.
    - **London Taxi Drivers (Maguire et al., 2000):** Compared to controls, taxi drivers had significantly *increased* grey matter volume in the **posterior hippocampus** (spatial navigation). The volume correlated *positively* with the amount of time spent as a taxi driver.
    - **Musicians (Elbert et al., 1995):** String players have a *larger* cortical map (representation) for the fingers of their (more active) left hand. These structural differences are linked to the *intensity of practice*.
    - **Mathematicians (Aydin et al., 2007):** Grey matter density in the **right inferior parietal region** was strongly correlated with the duration of time the person had spent as an academic mathematician.
    - **Juggling (Draganski et al., 2004):** After three months of training, subjects showed a significant *expansion* of grey matter in the **mid-temporal area (hMT/V5)** (motion processing). After three months of *no practice*, this expansion *decreased*, demonstrating the "use it or you will lose it" principle.

Given this overwhelming evidence, a pervasive shift from the 3D to the 2D world will inevitably be causing significant and widespread changes to our brains.

3. Effects on Identity and Relationship

This section explores how the "2D world," particularly social media, is fundamentally changing our concepts of self and our methods of social interaction.

Effects on Identity

The digital world provides a new medium for self-expression, which has led to new forms of identity. Psychological theories have proposed different versions of the self, and the digital world has added new layers:

- **Real (life) Self:** The conventional self, constrained by face-to-face social norms.
- **True Self (Carl Rogers, 1951):** The internal self, based on existing characteristics that are not always expressed in social life.
- **"Hoped-for, possible self" (Zhao et al., 2008):** This is the modern social media self. It

is a curated identity that represents not who we *are*, but who we *want to be* (or who we want others to think we are).

A KidScape (2011) survey found that 50% of young people (11-18) lie about personal details online to create identities that are "more sexy" or "more adventurous."

A study by **Meshi et al. (2016)** found that the *degree* of self-related sharing on Facebook was positively correlated with the resting-state functional connectivity between the **Medial Prefrontal Cortex (MPFC)** (self-referential thought) and the **Dorsolateral Prefrontal Cortex (DLPFC)** (executive function).

The Reward of Sharing and "Likes"

Sharing information about oneself is intrinsically rewarding. **Tamir & Mitchell (2012)** demonstrated that self-disclosure activates the brain's core reward systems—specifically the **Nucleus Accumbens (NAcc)**—in the same way that primary rewards like food and sex do.

Social media provides "Quantifiable Social Endorsement" (QSE) in the form of "likes," which powerfully leverages this reward circuitry, particularly in adolescents.

- An fMRI study by **Sherman et al. (2016)** found that viewing photos with *many* likes (vs. few) was associated with greater activity in the **Nucleus Accumbens (NAcc)**.
- Behaviourally, participants were more likely to "like" a photo (even of risky behaviour) if it was already popular.
- This NAcc responsivity to social reward appears to peak around age 16-17, highlighting a key window of vulnerability.
- The features of social media (instant gratification, unpredictability) make them powerful "dopamine triggers" (**Weinschenk, 2009**).

Effects on Social Relationships

The transition to a 2D world has changed the *quantity*, *quality*, and *style* of our social relationships.

While the number of online "friends" has grown (**Kanai et al., 2011**), the number of *true confidants* (people with whom one can discuss important matters) is declining (**McPherson et al., 2006**).

We are also spending less time in face-to-face interaction and more time in non-oral, text-based communication (Ofcom, 2012). This shift has a significant, measurable physiological consequence.
A key study by Seltzer et al. (2012) investigated the hormonal effects of different types of social support after a stress test:

- **Hormonal Results:**

    - **Full Contact** (in person) and **Verbal Contact** (by phone) led to an *increase* in **Oxytocin** (the "bonding" hormone) and a *decrease* in **Cortisol** (the "stress" hormone).
    - **Instant Message** (text only) and **No Contact** groups showed *no increase* in oxytocin and their cortisol levels *remained high*.
- **Conclusion:** The purely textual information in an instant message is *not enough* to provide physiological emotional support. The **prosodic cues** (the tone of voice) are critical.

This shift has been linked to a general **decline in empathy** (**Konrath et al., 2011**) and **deficits in face processing** (**He et al., 2011**). The N170 effect (a brainwave component for face processing) was found to be *significantly smaller* in excessive internet users (EIUs).

Finally, the **Nucleus Accumbens (NAcc)** is biologically linked to social media usage. Studies show NAcc sensitivity to reputation predicts Facebook use (**Meshi et al., 2013**), and *lower* NAcc volume is associated with *higher* frequency of checking Facebook (**Montag et al., 2017**), pointing to a potential biological basis for addictive-like behaviour.

4. Effects on Free Time, Aggression, and Attention

This section explores the impact of videogames, a primary "2D world" activity, on the brain's reward system, aggression, and attentional capabilities.

Videogames, Free Time, and Addiction

Videogaming is a dominant leisure activity, displacing other activities like reading and homework (Homer et al., 2012; Cummings & Vandewater, 2007).

This intense engagement is linked to the brain's reward system and **dopamine** (Weinstein & Lejoyeux, 2010). Studies show that frequent video game players show an **enlargement of the ventral striatum (NAcc)**, a feature also seen in pathological gamblers (Kühn et al., 2011).

This leads to a **"chicken and egg" dilemma**:

1. **The "Chicken" (Gaming changes the brain):** Kühn et al. (2011) found that the *more time* spent gaming, the more pronounced the expansion of the left ventral striatum.
2. **The "Egg" (The brain predisposes to gaming):** Erickson et al. (2010) found that the volume of the **dorsal striatum** (sensorimotor control) *before* training *predicted* skill acquisition in a new videogame.

A possible resolution is that a larger **dorsal striatum** might predispose someone to be *good* at games, while the *act of playing* then *changes* the **ventral striatum** (the reward system).

Different game genres are also linked to different **arousal** patterns (Metcalf & Pammer,

2014):

- **First-Person Shooters (FPS):** Linked to *higher* arousal during play ("thrill-seeking" model).
- **MMORPGs:** Linked to *decreased* arousal during play ("escapist" model).

Videogames and Aggression

A large body of research explores the link between violent videogames and aggression.

- **Behavioural Aggression:**
  - **Konijn et al. (2007):** Found that adolescent boys who "wishfully identified" with a *realistic violent* game character were the *most* aggressive, willing to use noise levels they believed could cause **permanent hearing damage** to a partner.
  - **Hasan et al. (2012):** Found that violent games increase "hostile expectation bias" (the tendency to perceive hostile intent), which in turn increases aggression.
- **Physiological Effects (Desensitisation):**
  - **Carnagey et al. (2007):** Participants who played a *violent* game showed a significantly *lower* heart rate (HR) and *lower* galvanic skin response (GSR) while watching videos of *real-life* violence. They were physiologically desensitised.
- **Brain Correlates:**
  - **Mathiak & Weber (2006):** fMRI studies show that playing violent games is correlated with *deactivation* in emotional regions like the **Rostral Anterior Cingulate (rACC)** and the **Amygdala**. This suggests emotional and empathetic brain regions are suppressed to allow the player to act violently without hesitation.

Videogames and Attention

The impact of gaming on attention is twofold, creating both benefits and deficits.

- **The "Bad" (Sustained Attention):**
  - Gaming is linked to more teacher-reported attention problems (Swing et al., 2010).
  - The link is *bidirectional*: gaming can lead to attention problems, and those with attention problems are drawn to gaming (Gentile et al., 2012).
  - Gaming experience is *negatively associated* with "proactive control," or the ability to sustain attention (Bailey et al., 2010).
- **The "Good" (Selective Attention):**
  - **Green & Bavelier (2003):** This classic study found that experienced action gamers were significantly better than non-gamers at visual *selective attention* tasks (e.g., tracking multiple objects). They proved causality by training non-gamers, who then showed the same improvements.
  - **Appelbaum et al. (2013):** Found that action gamers have improved visual sensitivity. They can "extract more information from a visual scene... and they do it faster."
  - **Real-World Application:** These skills are why experienced gamers have been shown

to make excellent drone pilots (McKinley et al., 2011).

5. Effects on Memory and Learning

This final section explores how constant information access and multitasking are changing cognitive functions related to learning.

The "Google Effect" (Transactive Memory)

The internet has become a primary form of "transactive memory," an external system where information is stored collectively outside ourselves.

A key study by **Sparrow, Liu, & Wegner** investigated this:

- **Experiment 1 (Priming):** When faced with difficult trivia questions, participants were *primed* to think of computer-related words.
- **Experiment 2 (Encoding):** The group that believed trivia statements would be *saved* had significantly *worse* memory for the information itself.
- **Experiment 3 & 4 (Remembering "Where" vs. "What"):** Participants had the best memory for the *content* of statements they believed had been **erased**. However, they were generally better at remembering *where* information was stored (i.e., which folder) than the information itself.
- **Conclusion:** We are adapting our memory to prioritise remembering *how to find* information (the "where") rather than the *information itself* (the "what"). This affects **semantic memory** (general facts).

Information Seeking (Googling)

The act of searching is a distinct cognitive skill that physically changes the brain.

- **Small et al.:** An fMRI study found that "Net Savvy" (experienced) older adults showed *increased* activation in regions for **decision-making and complex reasoning** while searching, compared to "Net Naïve" users. After just *five days* of training, the "Naïve" group's brains began to look like the "Savvy" group's.
- **Desjarlais:** An eye-tracking study found **High-Attention Students** used a *linear* search (search engine -> link -> search engine) and performed *better* on a comprehension test. **Low-Attention Students** jumped between hyperlinks in a non-linear way, got lost in irrelevant sources, and performed *worse*.

Reading on Paper vs. Screen

The physical medium we use for reading has a measurable impact on comprehension and fatigue.

- **Mangen et al.:** Students who read texts in **print** scored significantly *better* on a reading comprehension test than those who read the same text as a PDF.

- **Jeong:** This study confirmed that students had better reading comprehension from **paper books (p -books)** . Using CFF (critical flicker/fusion frequency) to measure eye fatigue, it also found students had *significantly greater* eye fatigue after reading **e-books** .

Media Multitasking and Cognitive Control

A defining feature of the digital world is "media multitasking." Research shows this is not a skill but a detriment to cognitive control.

- **Ophir et al. (2009):** This foundational study identified Heavy Media Multitaskers (HMMs) and Light Media Multitaskers (LMMs).
  - **Task (Filtering):** Participants were told to focus on red bars and ignore distracting blue bars.
  - **Finding:** The LMMs (Light Multitaskers) successfully ignored the distractors. The HMMs (Heavy Multitaskers) *could not* . Their performance got progressively *worse* as the number of distracting items increased.
  - **Conclusion:** Chronic media multitaskers are *not* better at multitasking. They are *worse* at a fundamental cognitive skill: **filtering out irrelevant information** .